

Pressure Trending Analysis to Support Cavern Integrity Monitoring at the U.S. Strategic Petroleum Reserve



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Presentation Outline

- ◆ The U.S. Strategic Petroleum Reserve
- ◆ Topic 1 – Static Cavern Pressurization Analysis
- ◆ Topic 2 – Adjacent Cavern Behavior and Their Effects on Pressurization Rates
- ◆ Topic 3 - Water Injection and Its Effects on Cavern Behavior



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The U.S. Strategic Petroleum Reserve

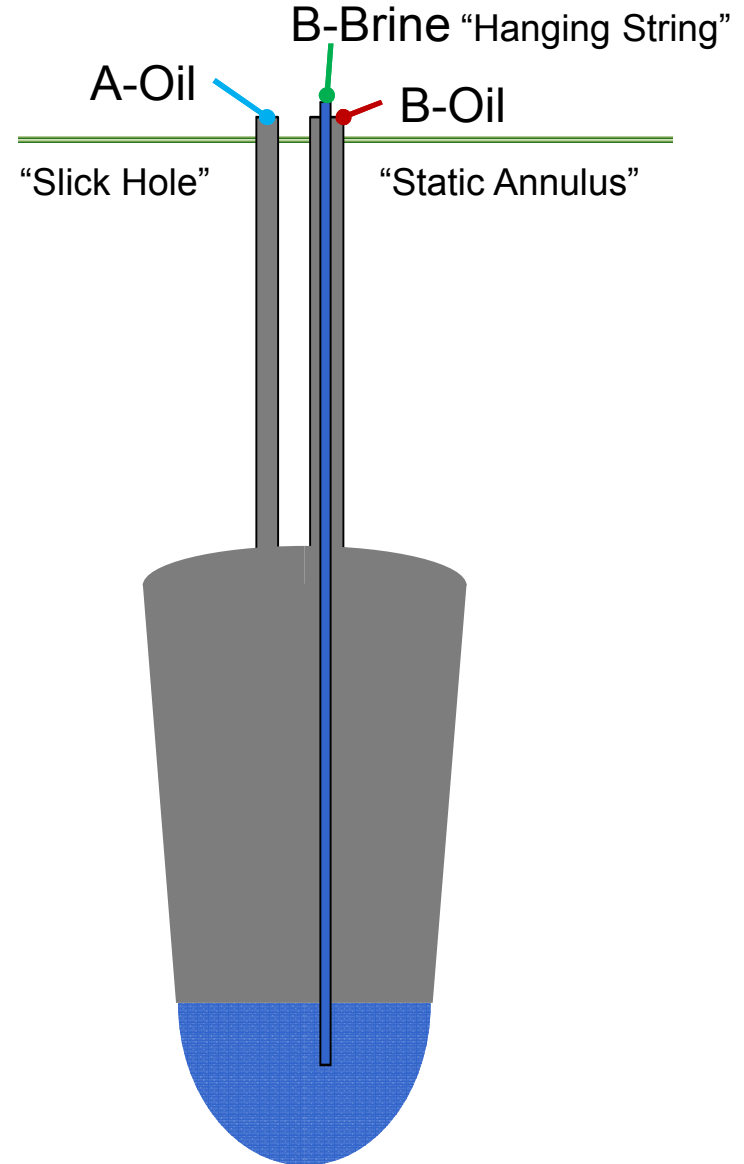
- ◆ Established by the Energy Conservation Act of 1975
- ◆ Largest emergency crude oil reserve in the world
- ◆ Drawdown is performed to reduce adverse economic impact of major petroleum supply interruption to the United States
- ◆ Four sites contain 695 MMbbl of crude oil
- ◆ 63 caverns, 120 wellbores



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Pressure Transmitters Monitor Caverns

- ◆ SPR continuously monitors cavern fluid pressures at three locations on typical 2-well cavern
 - A-Oil (Slick hole)
 - B-Oil (Static Annulus)
 - B-Brine (Hanging String)



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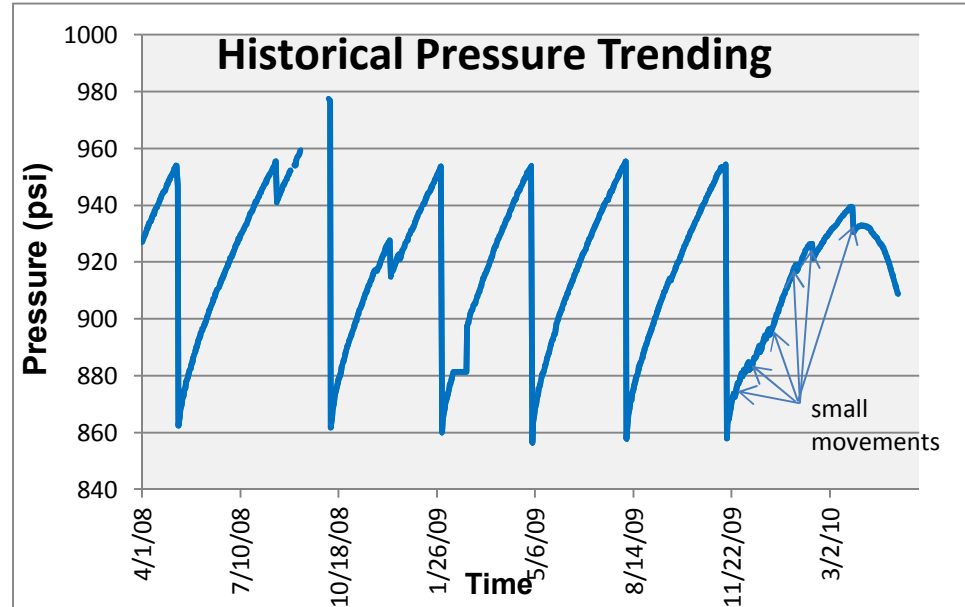
Topic 1 - Static Cavern Pressurization Analysis

◆ Historic Cavern Pressure Monitoring Program

- Daily cavern pressure data in Caveman
 - Analyzes fluid movements and flags “off normal” pressures
- Five year MIT

◆ Missed a problem

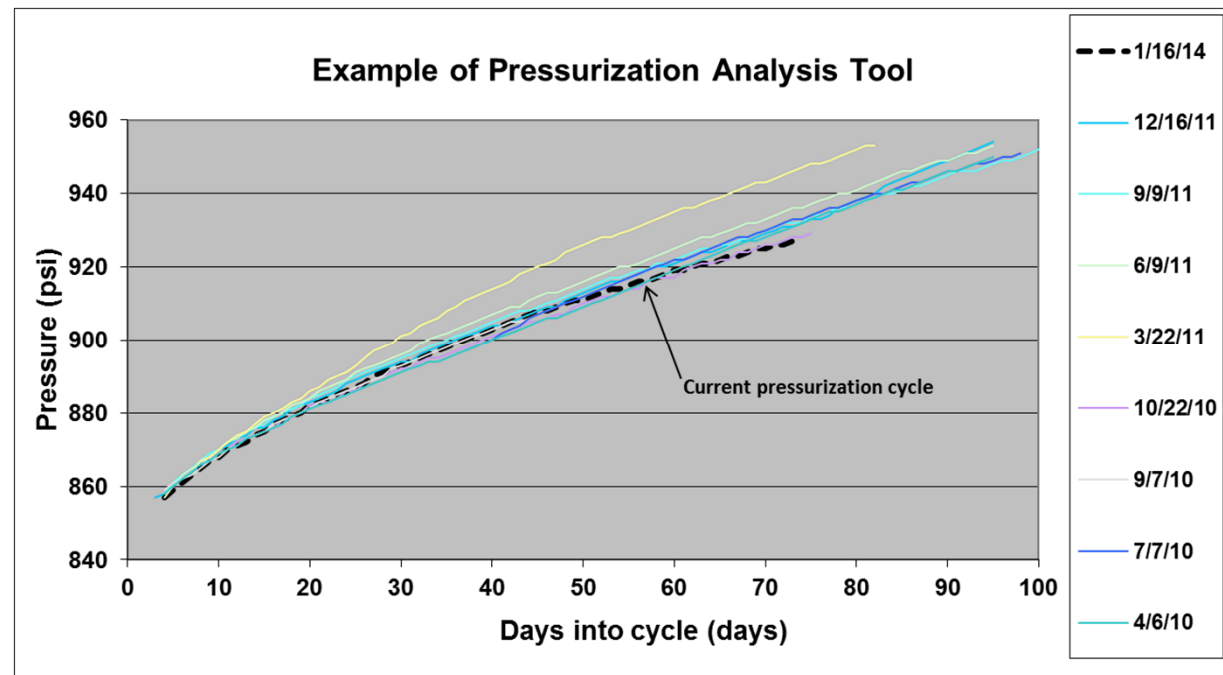
- Frequent small movements masked integrity issue



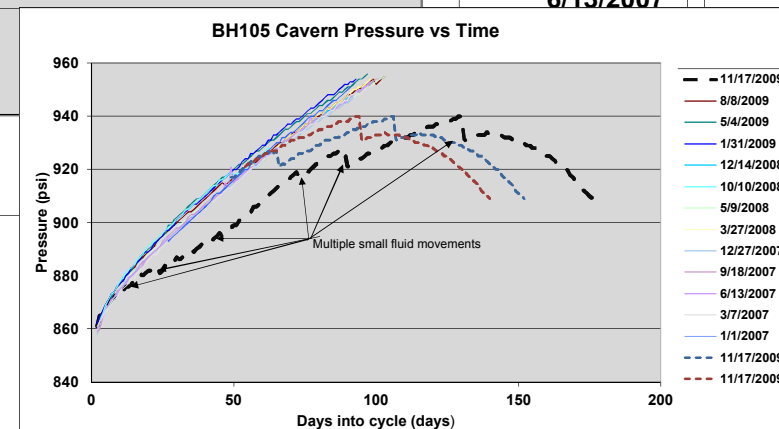
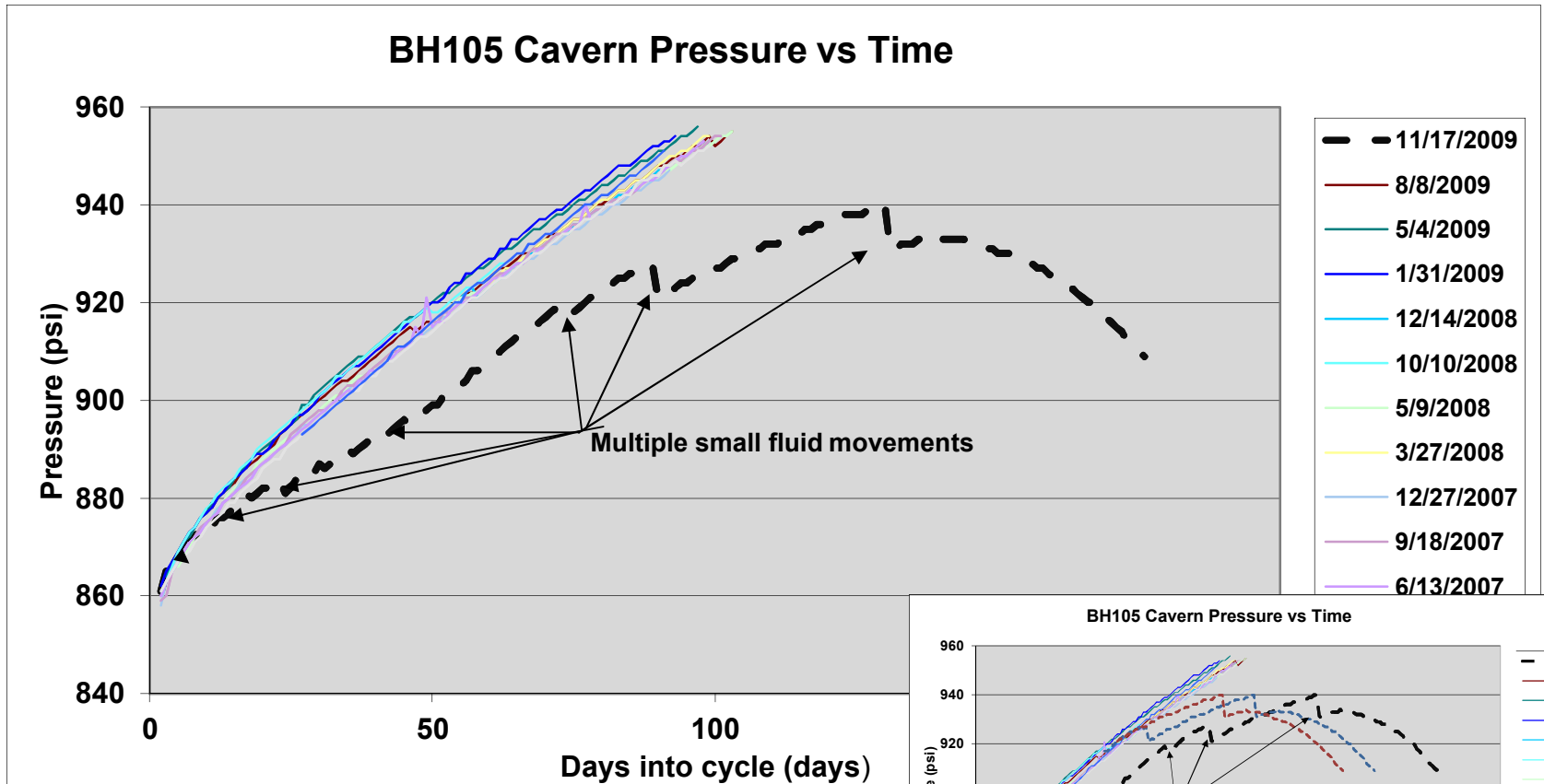
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Static Cavern Pressurization Analysis

- ◆ Found that by comparing pressure trend histories, repeatable cavern behavior can be identified
- ◆ Anomalous cavern pressure trends can also be identified

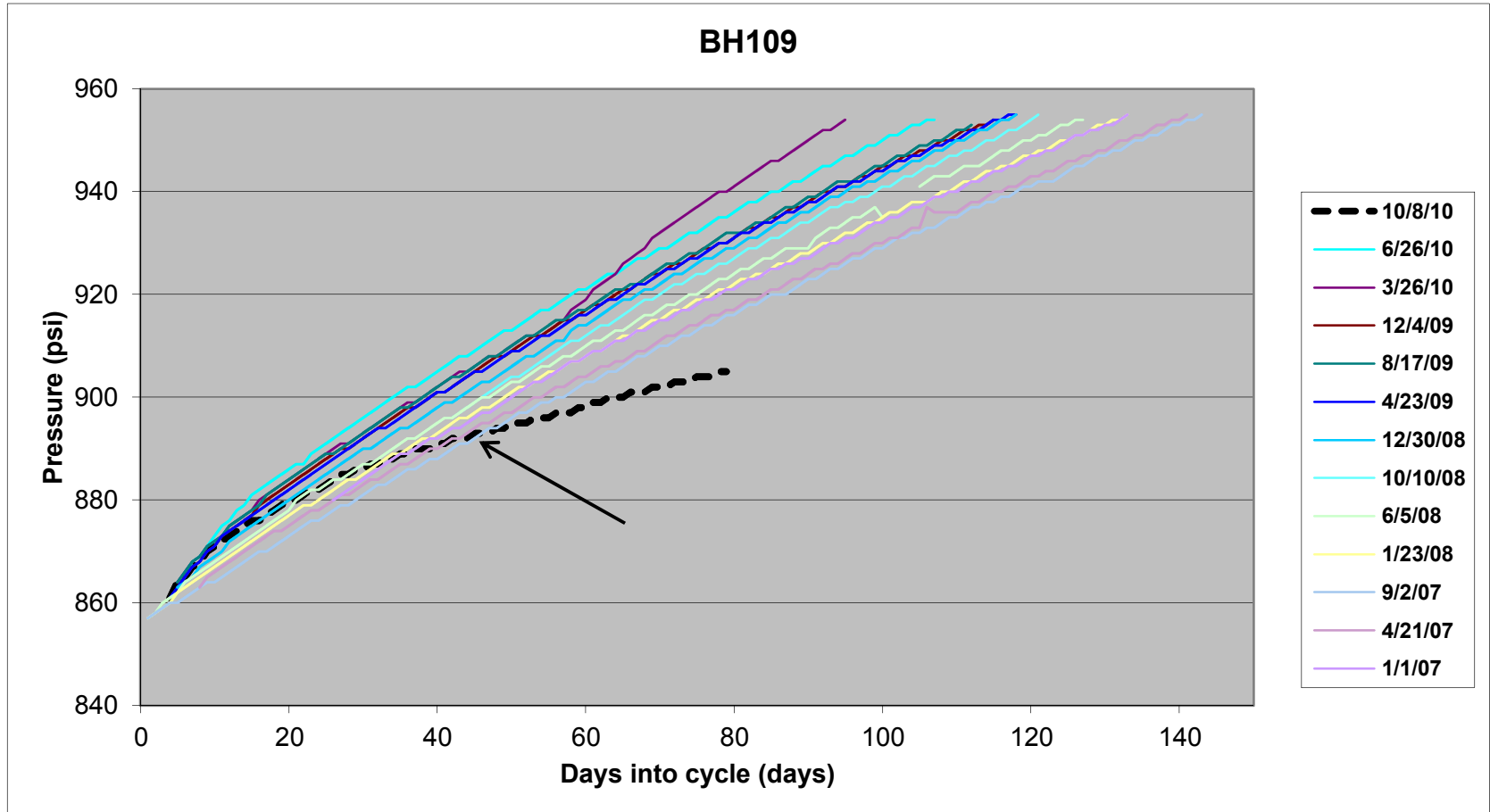


Pressurization Analysis Tool - Case Study 1



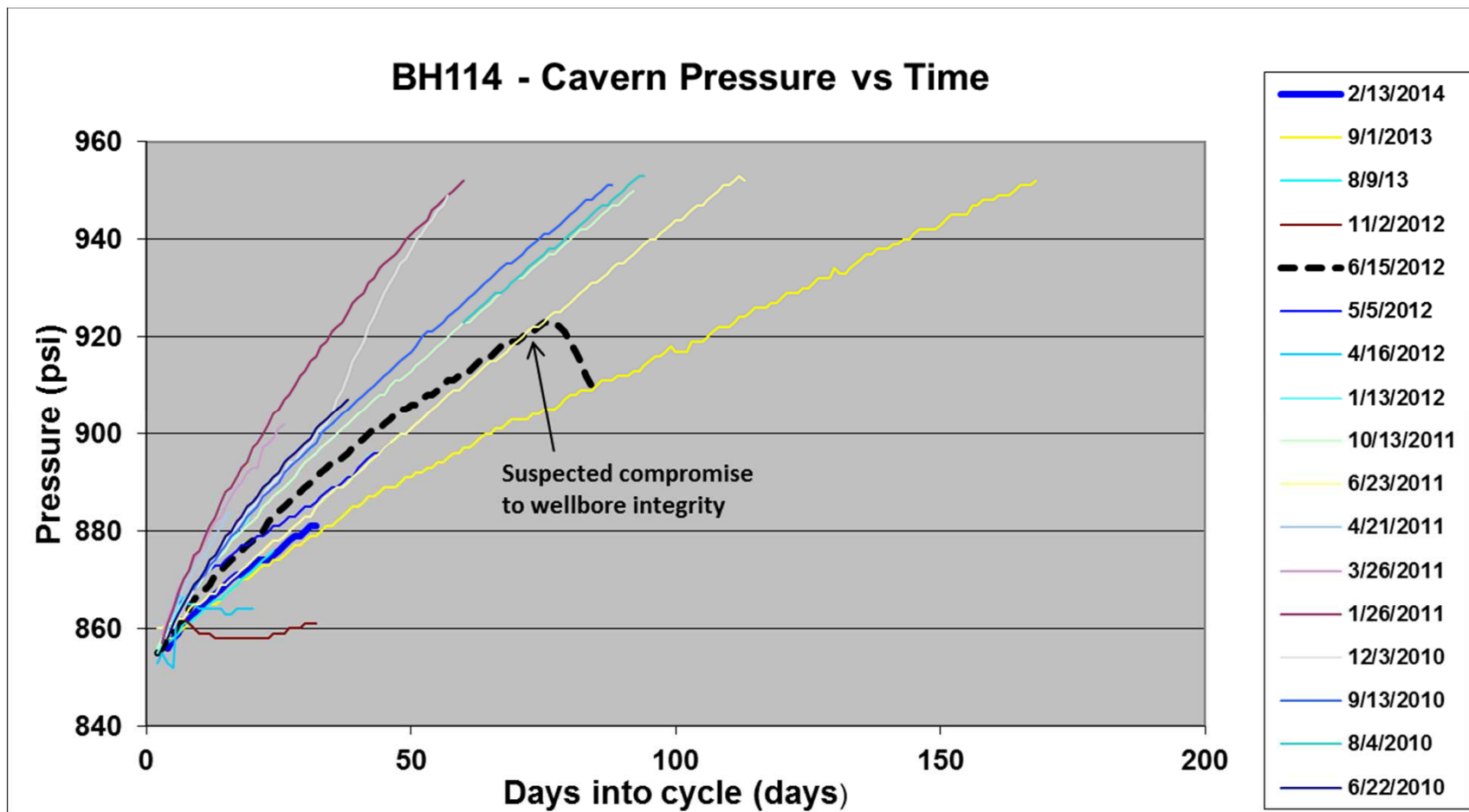
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Pressurization Analysis Tool - Case Study 2



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Pressurization Analysis Tool - Case Study 3



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Topic 1 Summary - Static Cavern Pressurization Analysis

- ◆ Monitoring tool provides real time early detection to find problems inside cavern wellbores
- ◆ Works best with static caverns
- ◆ Proven record of success in detecting wellbore integrity issues
- ◆ Resulted in early detection, led to further diagnostic work and wellbore repairs
- ◆ Prevented oil migration outside of cavern system
- ◆ Tool has been used as input into wellbore damage grading system



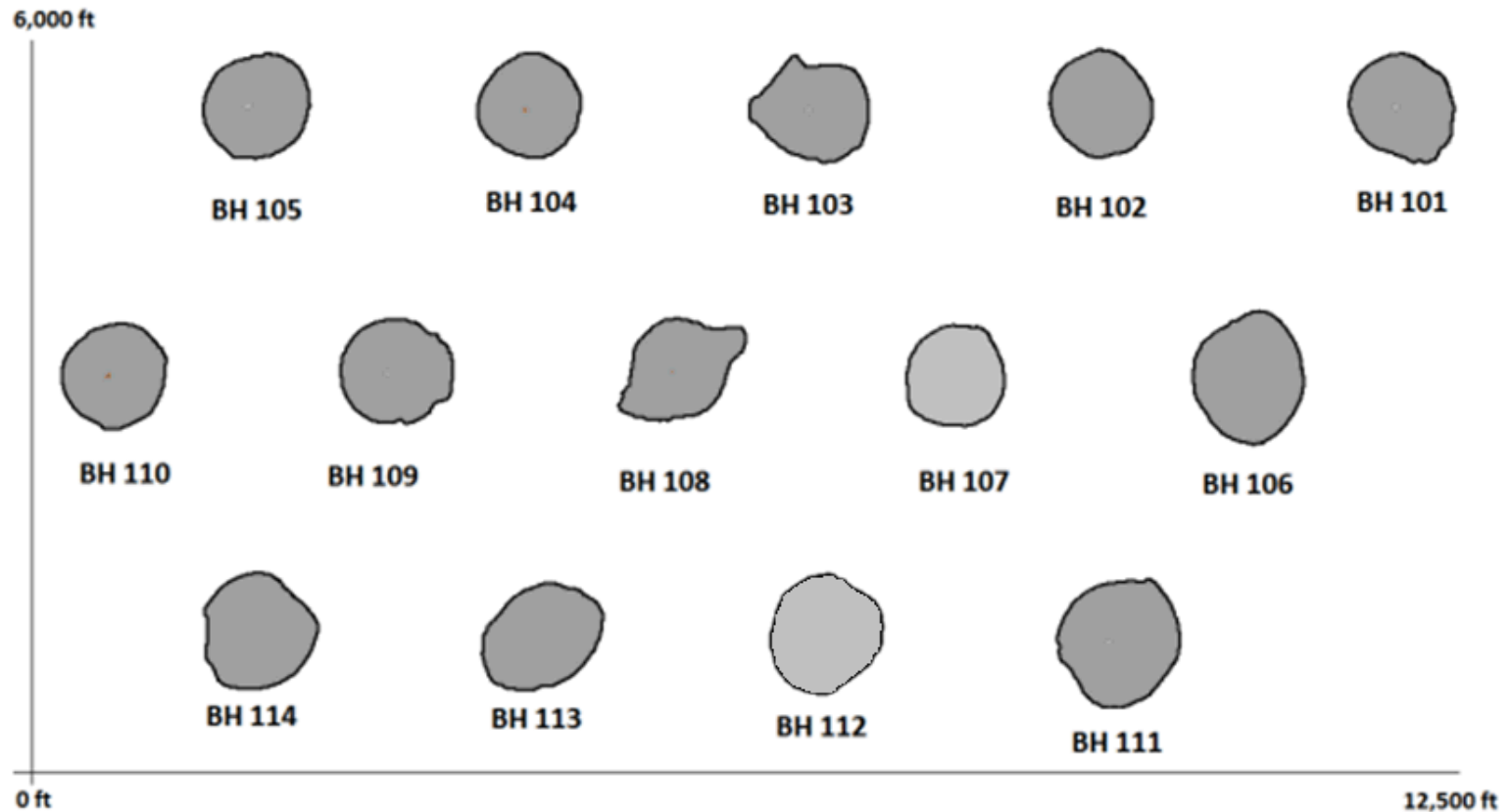
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Topic 2 – Adjacent Cavern Behavior and Their Effects on Pressurization Rates

- ◆ Salt behaves as visco-plastic material that creeps over time
- ◆ Cavern creep rate is a function of many factors
 - Salt characteristics, ullage, operating pressures, type of stored fluids
- ◆ Interdependencies between caverns within a single salt dome
- ◆ When analyzing individual cavern pressures, the behavior of adjacent caverns must be taken into account
- ◆ Four case studies provided

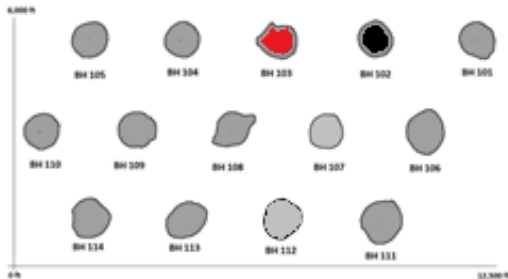


Adjacent Caverns - Planar View of Big Hill Caverns

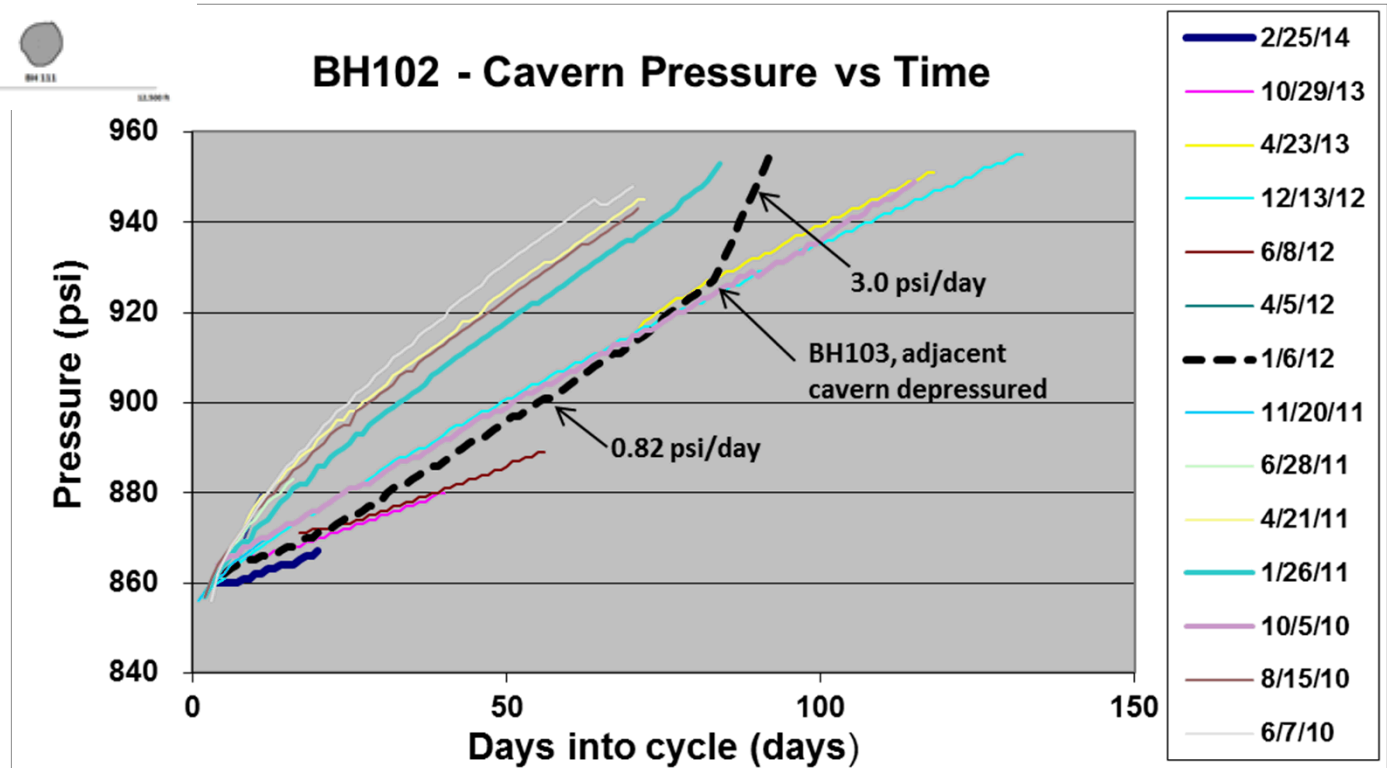


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Case Study 1 – BH102 Cavern

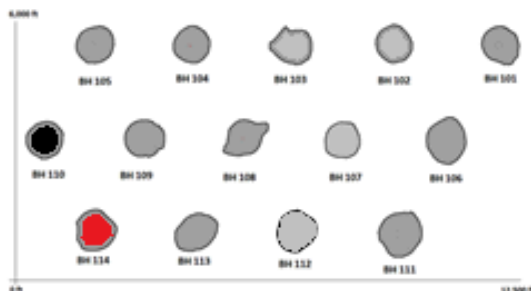


BH102 - Cavern Pressure vs Time

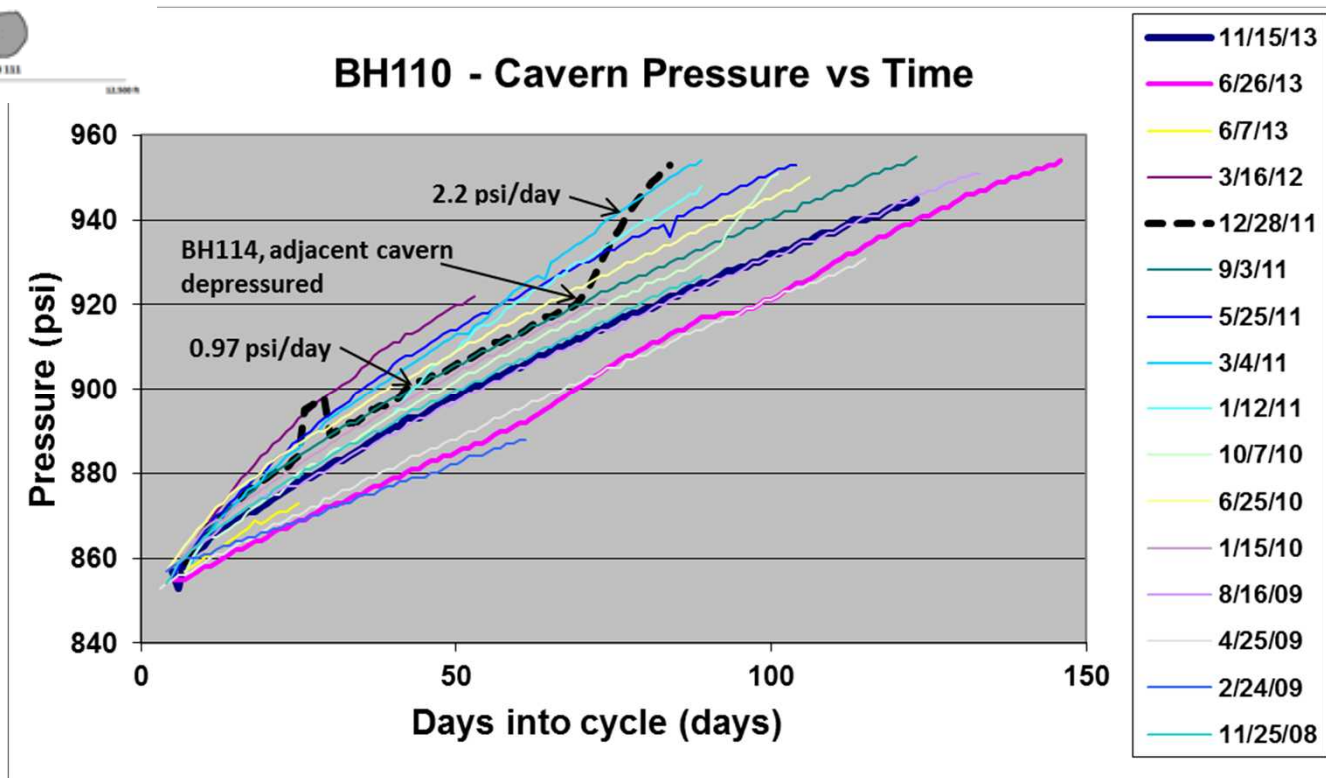


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Case Study 2 – BH110 Cavern

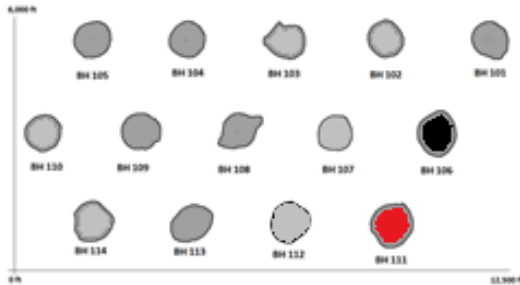


BH110 - Cavern Pressure vs Time

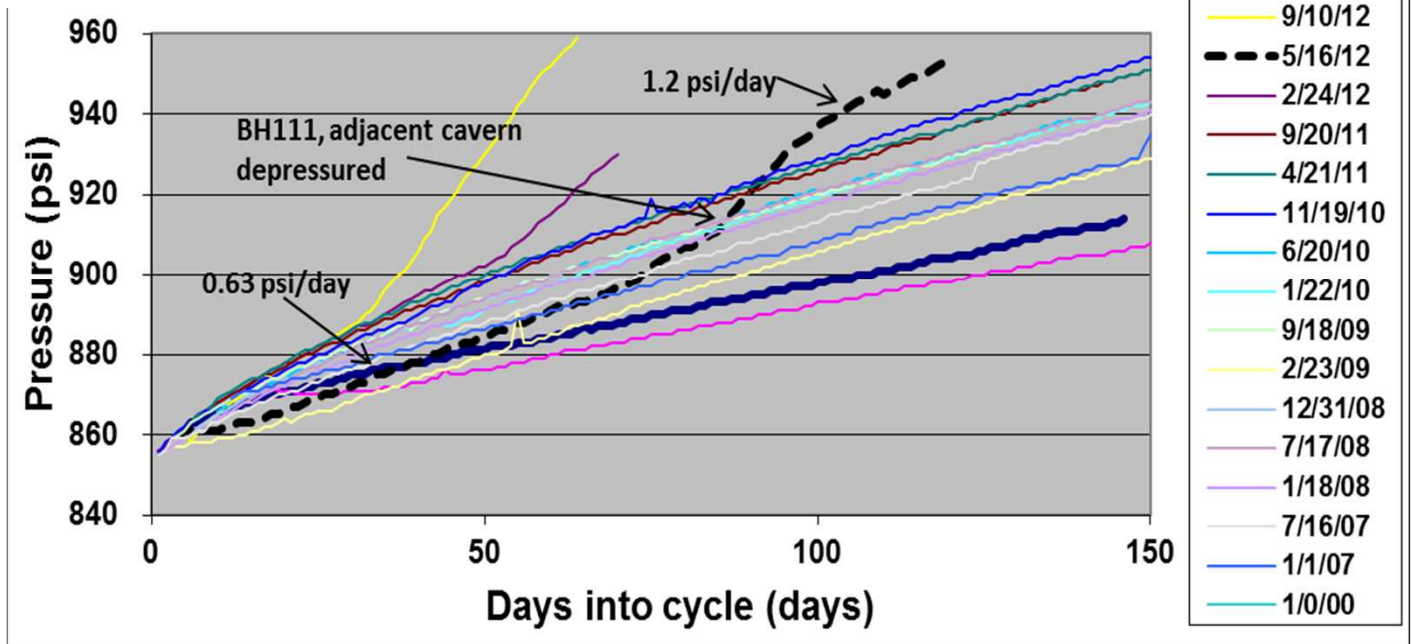


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Case Study 3 – BH106 Cavern

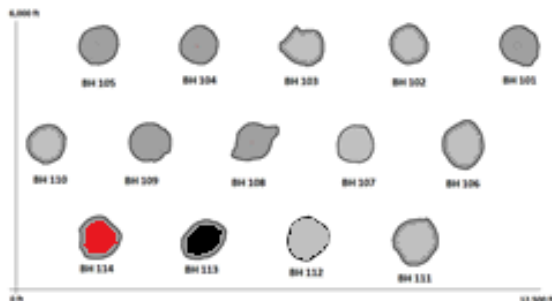


BH106 - Cavern Pressure vs Time

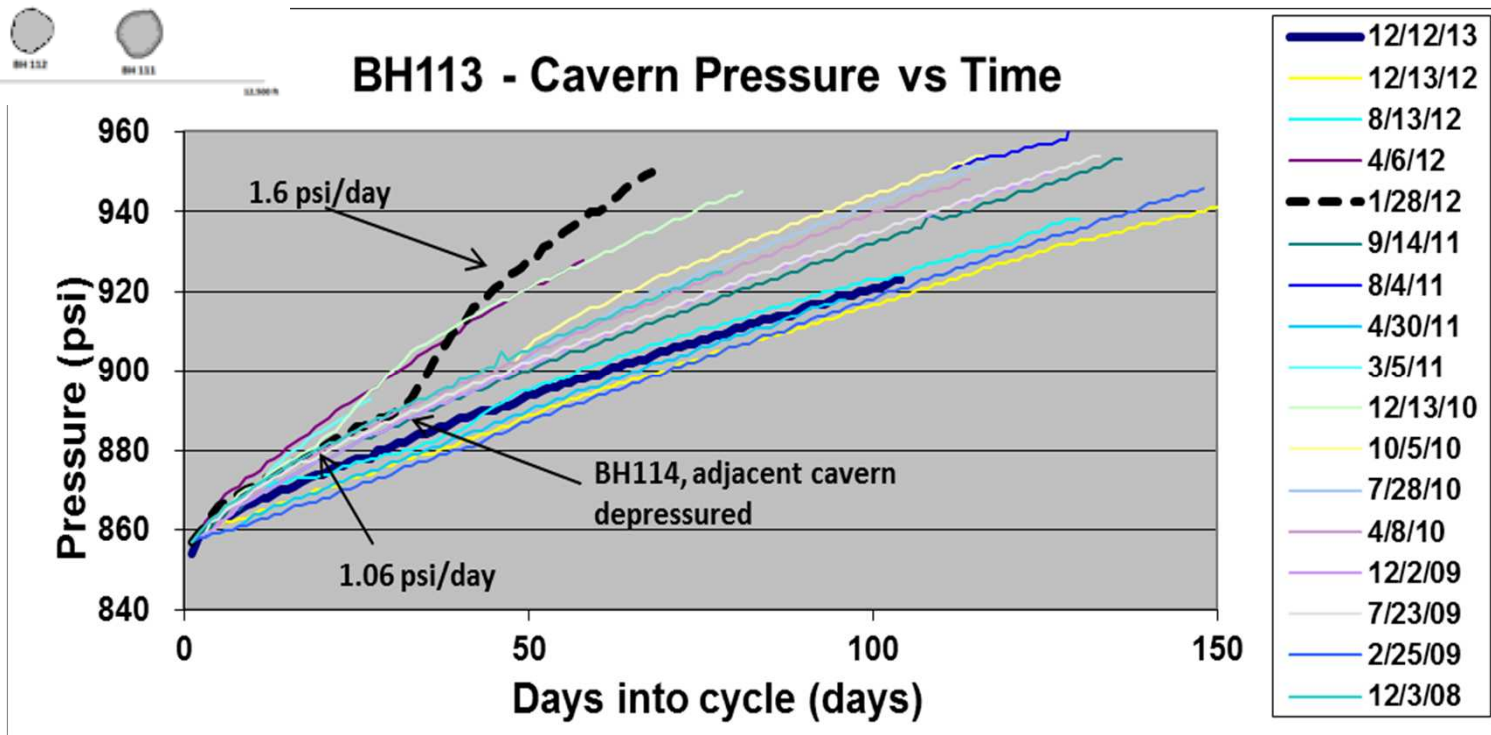


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Case Study 4 – BH113 Cavern



BH113 - Cavern Pressure vs Time



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Topic 2 Summary - Adjacent Cavern Behavior and Their Effects on Pressurization Rates

- ◆ Pressurization rates is a result of the geo-mechanics of the salt dome and caverns
- ◆ De-pressured adjacent cavern no longer supports the entire salt overburden between caverns
- ◆ Additional load results in pressuring up faster-than-normal
- ◆ Following a workover, cavern pressures return to normal operating pressure range



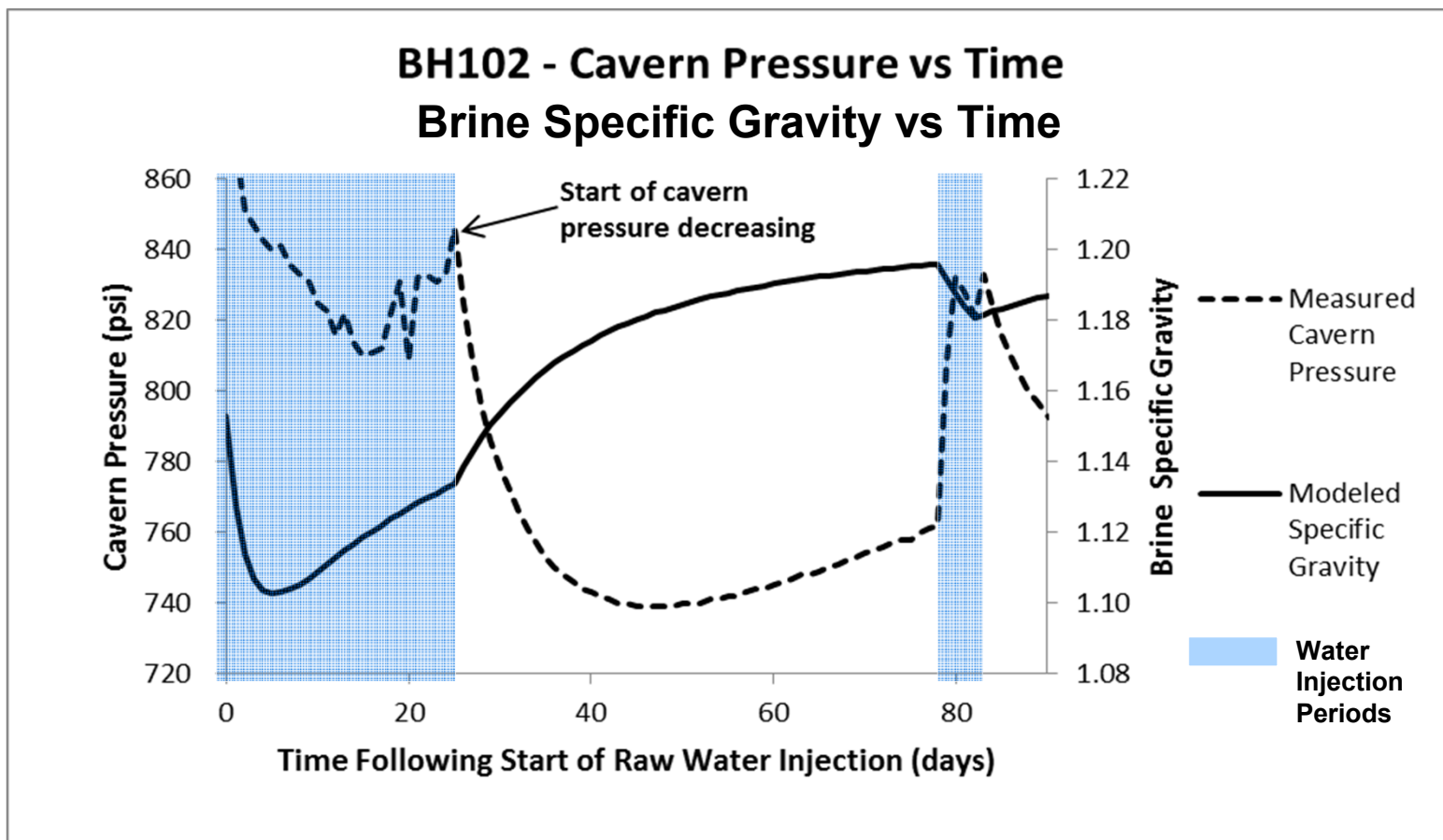
Topic 3 – Water Injection and Its Effects on Cavern Behavior

- ◆ Injecting unsaturated brine into a cavern will temporarily change observed cavern pressurization rate
- ◆ Dissolution ratio between volumes of raw water injected to cavern space created is “7 to 1”
- ◆ Average specific gravity of the cavern brine changes over leaching time period



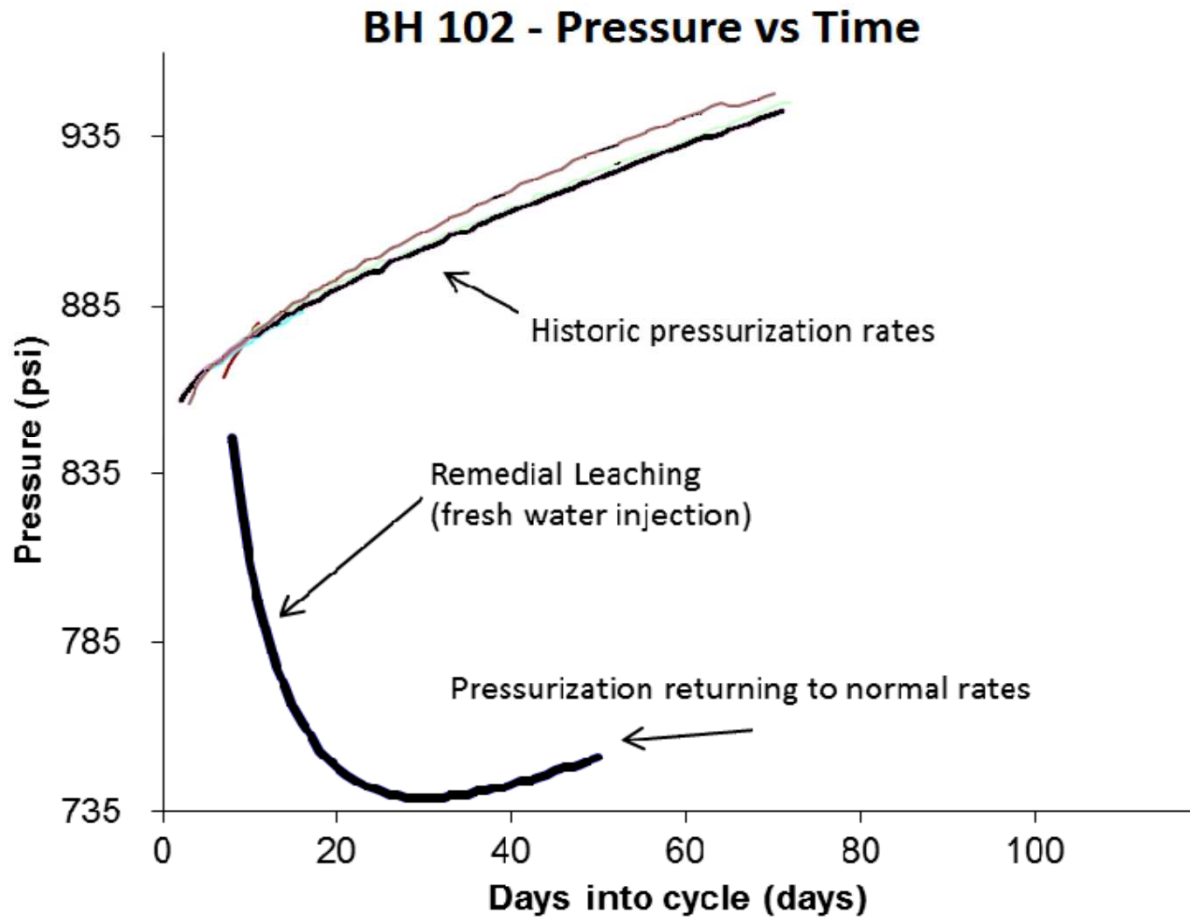
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Water Injection - BH102 Cavern Behavior



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Return to Normal Pressures



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Topic 3 Summary - Water Injection and Its Effects on Cavern Behavior

- ◆ Whenever water injection occurs, cavern pressures change accordingly
- ◆ No longer considered “static” cavern
- ◆ Pressurization rates are no longer used for wellbore integrity evaluation purposes



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Presentation Main Conclusions

- ◆ Topic 1 – Static Cavern Pressurization Analysis
 - Monitoring tool provides real time early detection to find problems inside cavern wellbores
- ◆ Topic 2 – Adjacent Cavern Behavior and Their Effects on Pressurization Rates
 - Caverns do not behave independently of each other
 - They are dependent on many factors including the pressure behavior of adjacent caverns
- ◆ Topic 3 - Water Injection and Its Effects on Cavern Behavior
 - Leaching disrupts the pressure analysis tool because of dissolution of salt and the loss of static conditions



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